THE

NEW NAVIGATION

Presented in a Familiar Way for Captains and Officers of the Merchant : : : Service : : :

By F. C. Cross

Lieut. R.N.R.

Head Master White Star Training Ship "Mersey"

2/- Net

GLASGOW: JAMES BROWN & SON, Publishers
The Nautical Press, 52 Darnley Street

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INTRODUCTION.

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HAVING taken some small part in the navigation of some of our modern liners, I have noticed that in very rare instances is the "Marcq St. Hilaire" method (commonly called "New Navigation") used in practical work, and on asking many men why they did not use it, the almost invariable reply was that the thing was full of versines and natural numbers, etc., that they knew nothing about. This appears to be our general attitude in the Merchant Service; we will not have anything to do with versines, natural or otherwise, and only accept the haversine in the chronometer because the text books for Board of Trade examinations have of late years given it. So my object in issuing this little booklet is to present this problem in a form that all our merchant officers are familiar with.

Its undoubted advantages, once known and appreciated, are sufficient to place it above all others as *the* problem to use under almost any conditions.

In the first place, it can be used when the double altitude problem is more or less unreliable owing to the sun being obscured until rather late for the second observation.

The navigator need not worry about P.V. sights, for as long as the altitude is under about 75° or even a little more, the method is available, whatever the bearing of the object.

The method is the same for either solar or stellar observations, save that the stellar are perhaps a little simpler

The run between sights needs very little consideration, thus obviating carrying the first position on to the second, so making some of the same logarithms available for the second observation.

From personal experience I can recommend this problem on the score of accuracy, as the daily position by this method on the *Mersey* is always on the dot (as compared with the latitude obtained by meridian altitude, etc.), when the double altitude is frequently 2′ or 3′ out both in latitude and longitude owing to a late second sight.

Another advantage of this problem was pointed out to me by a navigator in the Navy (where this method is used almost exclusively), viz., that as the altitude is the last thing to be worked with, an hour angle may be assumed for the second observation and all the calculation finished before taking the altitude. In which case find the G.M.T. corresponding to the hour angle used, and then the time-taker sings out "stop" to the observer, who takes the altitude at that precise second, from which is obtained the true zenith distance, which is compared with the one already calculated, and so the position is obtained within 2 or 3 minutes of the observation. Should the sun be clouded at that precise second, by altering the D.R. longitude, the time may be made to give the same hour angle as at the time when the altitude was really taken.

In the Western Ocean, also from the Cape to Australia, this problem should be especially valuable, as the weather conditions, more often than not, preclude the observer from choosing his own times for sights, and the following examples will clearly show the extreme flexibility of this problem.

EXPLANATION.

EXPLANATION.

IN the "New Navigation" we obtain the distance of the object from our zenith by taking its true altitude from 90°, then with our D.R. position we calculate the same line, viz., the zenith distance.

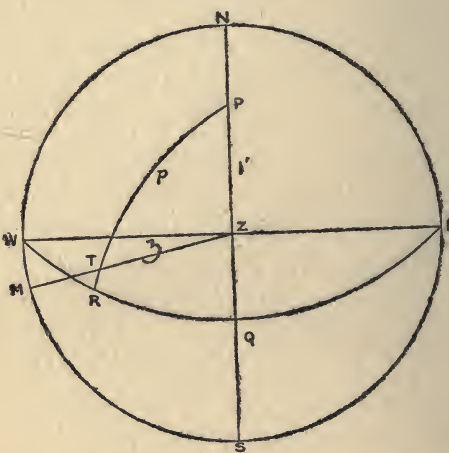
If our D.R. is right, then, of course, the true and calculated zenith distances will agree; if they do not do so, then the data used (the D.R. latitude and longitude) must be wrong; so by comparing the two and noticing whether we are nearer to, or further from, the object, we can correct the D.R. by means of Sumner lines.

With the D.R. position as a starting point, we lay off the distance to or away from the body, along the respective bearings for the times of observation (obtained from Burdwood, Davis or A B C tables). These points, so obtained on the bearing lines, each represent the spot crossed by the respective Sumner line, which, of course, is at right angles to the body's bearing of that observation, and, further, the point of intersection of the two Sumner lines is the actual position of the observer.

Now as to the method of calculating the zenith distance, it is simply a case of two sides and the included angle of a spherical triangle given to find the third side direct when the two sides are the polar distances (p), and the co-latitude (l^1), the included angle being the hour angle from noon. The formulæ we will use are the ones used for finding distance on a Great Circle, which should be familiar to most of us. For those who are interested in the "theory," I append the investigation of the formulæ used; those who are not interested can go straight on to the practical part.

It is not claimed that this is the best or simplest method of calculating the third side direct, but simply that it is the way in which we of the Merchant Service usually determine our third side in the "Great Circle" problem, and therefore, being familiar with the methods used, this present problem will be the more easily understood and quickly picked up. Once the principle is grasped the intelligent navigator will speedily cast about for a shorter and more speedy method.

I recommend those to read Mr. H. B. Goodwin's articles on the use of the haversine, as published in the *Nautical Magazine* of July and August, 1910.



Let $NWSE$ represent the rational horizon, P the elevated pole, $NPZS$ the observer's meridian, WZE the prime vertical, Z the zenith, WQE the equinoctial, T the position of the body when observed. Through T draw PR circle of declination, and ZM a circle of altitude. Then PZ (l') equals the co-latitude, TM the altitude of the body, so ZT (z) equals the zenith distance. RT is the declination, so PT (p) is the polar distance.

Now in the spherical triangle ZPT, from the fundament formula :—

$$\begin{aligned}
\text{Cos. } z &= \text{Cos. } p \text{ Cos. } l^1 + \text{Sine } p \text{ Sine } l^1 \text{ Cos. P} \\
&= \text{Cos. } p \text{ Cos. } l^1 + \text{Sine } p \text{ Sine } l^1 \left(2 \text{Cos.}^2 \frac{\text{P}}{2} - 1\right) \\
&= (\text{Cos. } p \text{ Cos. } l^1 - \text{Sine } p \text{ Sine } l^1) + 2 \text{Cos.}^2 \frac{\text{P}}{2} \text{ Sine } p \text{ Sine } l^1 \\
&= \text{Cos. } (p + l^1) + 2 \text{ Cos.}^2 \frac{\text{P}}{2} \text{ Sine } p \text{ Sine } l^1
\end{aligned}$$

$$1 - \text{Cos. } z = 1 - \text{Cos. } (p + l^1) - 2 \text{ Cos.}^2 \frac{\text{P}}{2} \text{ Sine } p \text{ Sine } l^1$$

$$\text{Hav. } z = \text{Sine}^2 \frac{p + l^1}{2} - \text{Cos.}^2 \frac{\text{P}}{2} \text{ Sine } p \text{ Sine } l^1$$

$$\text{Let Sine}^2\, \theta = \text{Cos.}^2 \frac{\text{P}}{2} \text{ Sine } p \text{ Sine } l^1$$

$$\text{Hav. } z = \text{Sine}^2 \frac{\text{P} + l^1}{2} - \text{Sine}^2\, \theta$$

$$\text{Hav. } z = \text{Sine} \left(\frac{p + l^1}{2} + \theta\right) \quad \text{Sine} \left(\frac{p + l^1}{2} - \theta\right)$$

$$\text{When Sine } \theta = \sqrt{\text{Cos.}^2 \frac{\text{P}}{2} \text{ Sine } p \text{ Sine } l'}$$

So to obtain our zenith distance we have to work out these two formulæ which take a very simple form, as follows :—

G.M.T.
Long.

M.T.P.
E.T.

A.T.P. (diff. from 24 hours)
24 0 0

Hour Angle
$\frac{\text{H}}{2}$ $\begin{cases}\text{Cosine} \\ \text{Cosine}\end{cases}$
p Sine
l^1 Sine
2)

2)

$\frac{p + l^1}{2} =$ As a Sine $= \theta$
θ

$\frac{p + l^1}{2} + \theta$ Sine
$\frac{p + l^1}{2} - \theta$ Sine

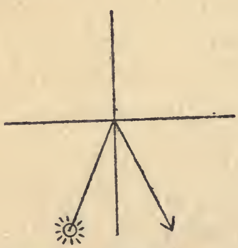
Z Dist. (cal.) = as a Hav. $= Z$ d.

Same form for the second observation.

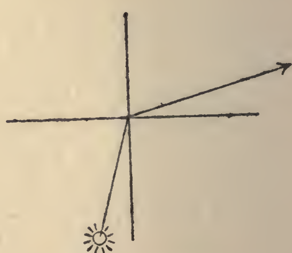
In the second computation use the same D.R. position as the first, as long as the run between the two observations does not exceed, say, 20 miles, but if a big run such as in the 20-knot ships for an interval of two hours, use as a D.R. position a point somewhere about half-way between the two observations. As before, use the same for both observations, and this will answer the purpose quite satisfactorily.

The run can be applied when projecting the final part of the problem, or, if preferred, a correction can be applied to the first altitude. The correction is obtained from the formula :—Correction for run = distance run × cosine of included angle between ship's head and sun's bearing at first observation. This can be worked by the traverse table as follows :—

Take the included angle, *or its supplement*, if over 90° as a course, the distance run in the distance column. Then the corresponding difference latitude gives the correction to be added to the first altitude if the included angle is under 90°, and subtracted if over 90°, the reason of which is obvious, for if the angle is under 90° we are approaching the body and increasing the altitude, whilst if over 90° we are receding from the body and so decreasing the altitude. The two figures show this clearly :—



Increasing the Altitude.



Decreasing the Altitude.

There is only one point to guard against regarding the projection of the final part of this problem, viz., that all distances measured east or west will be departure, so will have to be changed into difference of longitude before being applied to the D.R. longitude, and when, as in Example 3, laying down the two positions the diff. longitude must be changed into dep. The rules for changing dep. into diff. longitude and *vice versa*, by aid of the traverse tables, are very simple, as follows:—

Dep. into Diff. Longitude.—With the latitude as a course and the dep. in the diff. latitude column, the corresponding distance is the diff. longitude.

Diff. Longitude into Dep.—With the latitude as a course and the diff. longitude in the distance column, the corresponding diff. latitude gives the dep.

There are methods of calculating this final portion of the problem, but they do not possess the practical simplicity of the projection, which will be familiar to every practical navigator, so I have ignored them altogether. The instruments required are the chart-room dividers and the ordinary 6-inch wooden protractor that most officers carry in their pockets. Also, if possible, use a work book whose pages are ruled into squares, as it will help in drawing the right angles and bearings generally. There should be no difficulty in obtaining such work books, as nearly all schools use such books for graph work nowadays. I know in Liverpool the "Conways" use them, so they are obtainable there easily enough.

BRIEF RULES FOR PRACTICAL CALCULATION (SOLAR).

1. First determine the D.R. position. If the run is likely to be under, say, 20 miles, take the D.R. position

for the time of the first observation or thereabouts, but if the run is likely to exceed 30 miles, take the D.R. position roughly half-way between the observations.

2. Correct the declination and equation of time for G.M.T.

3. To the corrected chronometer time (G.M.T.) apply the longitude; if east, add; if west, subtract; this gives the mean time of observation (M.T.P.), then apply the corrected equation of time as directed to be applied to M.T. at the top of the column, which will give the apparent time of observation (A.T.P.). The difference between this and 24 hours gives the hour angle.

4. Under the hour angle write half the hour angle, under that place (p) polar distance ($90° \pm$ declination) and (l^1) the co-latitude ($90° -$ latitude).

5. Add p and l^1 and divide by 2.

6. Look out the cosine of the half-hour angle and write it down twice (for the formula says "cosine squared"), under them, the log. sines of p and l^1. Add these, rejecting 20 and divide by 2. This result looked out as a sine gives the angle θ, which is added to and subtracted from $\frac{p + l^1}{2}$.

7. The log. sines of these two values are then looked out and added together, the resulting log. looked out as a haversine in degrees and minutes giving the calculated zenith distance.

8. Opposite this write the body's azimuth at the time of observation from either Davis, Burdwood, or the A B C Tables.

9. Next take the observed altitude, correct it, subtract from 90°, which gives the true zenith distance. (*See* note.) Take the difference between the true and

calculated zenith distances marking the difference—or, as it is called, the "intercept"—*nearer* if the true is less than the calculated and *away* if the true is greater than the calculated.

10. Repeat the process for the second observation.

Note.—If the run between observations is not wished to be projected, the correction must be applied to the first altitude before subtracting it from 90°; it is applied according to the rules given in the last section. Which of the two is done is, of course, a mere matter of choice, although it really seems simpler to apply the correction for run and so finish with it. In all the examples following this has been done, as it certainly has the advantage of needing fewer lines to be drawn, thus making the projection simpler. The declination and equation of time in all these examples have been corrected by inspection, which, if done carefully, is quite accurate enough for practical work.

Rules for Stellar Observations.

The only difference for stellar work is in determining the hour angle. The formula for finding the hour angle is—

mean [illegible] right ascension

Hour angle = M.T.P. + M.S.R.A. – Body's R.A.
or Hour angle = A.T.P. + A.S.R.A. – Body's R.A.

so instead of looking out equation of time, look out the sidereal time, which is to be accelerated in the usual way for the hours and minutes of the Greenwich date, giving the M.S.R.A. *See* note as to method for "acceleration of sidereal time." The body's R.A. is looked out at the same time as the body's declination, so correct the chronometer time (G.M.T.) for longitude; if east, add; if west,

subtract; this gives M.T.P. Add to this the M.S.R.A., then subtract the body's R.A.; this gives the body's hour angle.

After the hour angle is obtained proceed as before, as the rest of the work is the same, though simpler, inasmuch as there will be no correction for run to apply to the first altitude, as the observations were practically simultaneous.

If taking stars with a run between observations, of course, apply correction for the run to the first altitude in the usual way. This completes the calculation in both cases.

Note.—To correct the sidereal time by inspection the old sea method may be employed which is perfectly accurate. The rule is as follows :—

Take the hours and decimals of an hour in the Greenwich date that we are accelerating for, then, disregarding the decimal point, call this quantity seconds.

If the hours are	between	1	and	7	subtract	1 second.
,,	,,	7	,,	17	,,	2 seconds.
,,	,,	17	,,	24	,,	3 seconds.

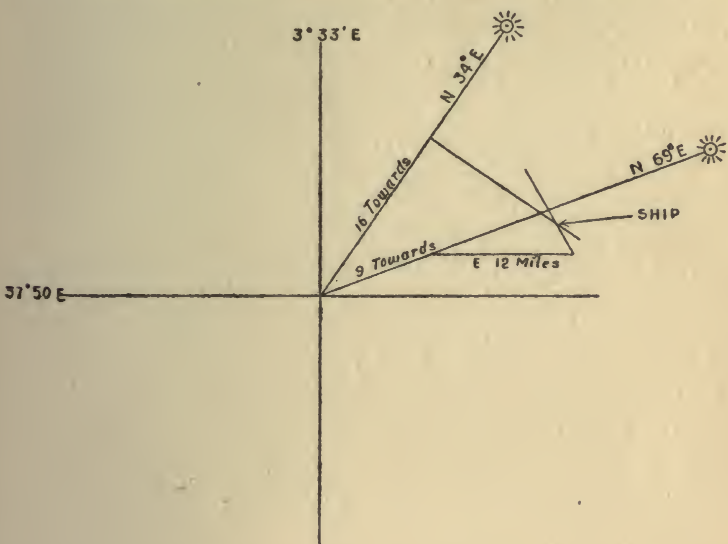
This result gives the acceleration to be applied to the sidereal time in seconds.

For 8 hours 48 minutes the acceleration will be 86 – 2, viz., 86 seconds, 1 minute 26 seconds.

Then proceed with the projection. First with the small protractor draw a vertical line to represent the longitude, and at right angles a horizontal line to represent the latitude. Mark them each with the latitude and longitude they represent, the point of intersection representing the D.R. position used. Suppose, for example, this position is latitude 37° 50′ S. and longitude 3° 33′ E., the first intercept 9′ towards the sun,

bearing at first observation N. 69° E., the second intercept 16′ nearer to the sun, bearing at second observation N. 34° E. The run between sights was E. 12′.

Lay off lines representing the bearings of the sun, then with the protractor lay off the intercepts, in this case both towards the sun. Scale used here $\frac{1}{16}$ of an inch to a

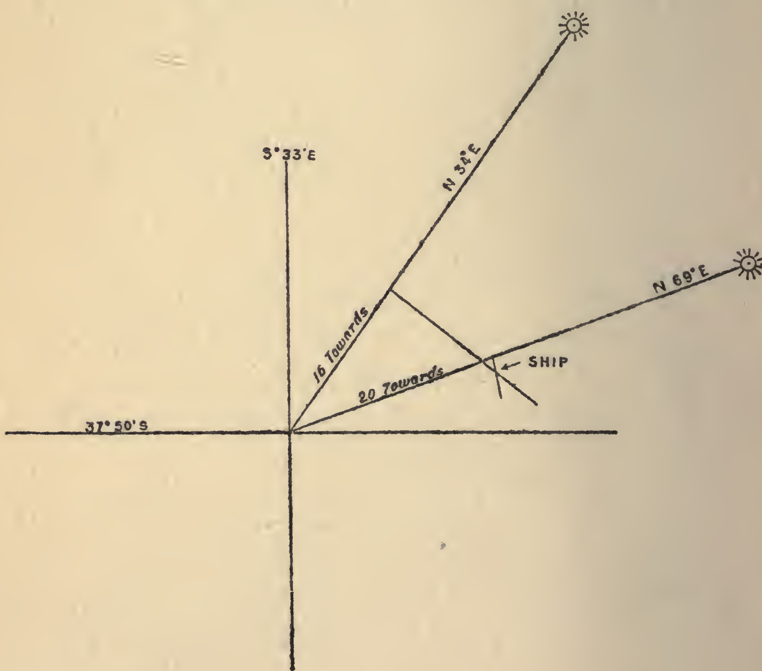


mile, any scale that is convenient doing equally well. From the point on the first bearing line, lay off the run, also measured on the same scale. At the end of the run draw a line at right angles to the first bearing line; through the second intercept point draw a line at right angles to the second bearing line; the point of intersection of these is the position of the ship. Measure the distance of this point from the parallel by the same scale. In this case it is 6½ sixteenths, viz., 6½ miles of different latitude and north of the D.R. line, its distance from the meridian being 20 sixteenths to the eastward. This, always

remember, is departure, the corresponding diff. longitude being $25\frac{1}{2}$ E.

Apply these differences of latitude and longitude to the D.R. position, and we have the position of the ship at the second observation.

Let us take the same case and apply the correction for the run to the first altitude instead of projecting it, the run being E. 12′. In the traverse table under 21° (the angle between the first bearing and the ship's head) and distance 12, the corresponding diff. latitude is 11·2, viz., the correction to apply to the first altitude, additive because the included angle is under 90°. This makes our first intercept 11′ more, viz., 20′. So to project similarly, leaving out the run, we have :—



In this case the lines drawn through the intercept points themselves, at right angles to the bearings, will intersect at the position of the ship, which makes the projection simpler and more speedy. One last thing before proceeding to the practical work; if the run is likely to be much more than 30′, it will be safer to use the D.R. position for each observation and combine two projections. An example will be found later on which will explain this. (*See* No. 3.)

Example No. 5 is especially put in to show the extreme flexibility of the problem.

I am indebted to Cadet G. H. L. Jones, who has worked most of the examples for me.

EXAMPLES.

Double Altitude of the Sun with a Run between Sights.

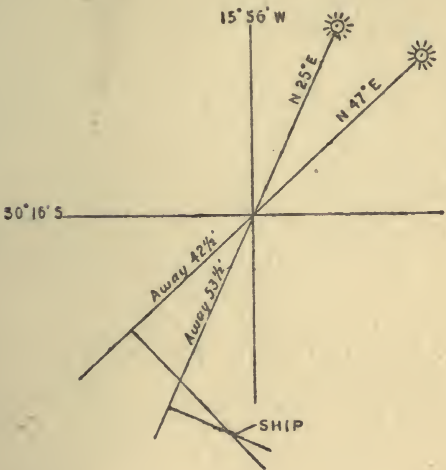
1910. September 16th, about 10 a.m. at ship. Latitude 30° 16′ S., longitude 15° 56′ W. D.R.; the observed altitude of ☉, was 45° 2′. Chronometer showed G.M.T. 10h. 56m. 44s., later, 11h. 15m. Observation altitude ☉ was 52° 38′. Chronometer showed G.M.T. 12h. 0m. 21s., height 20 feet. Ship made in the interval S. 9° E., 6 miles, also the same run to noon. Find the noon position of the ship.

Greenwich Date.	d h m s	Longitude.	
Sept.	15 22 56 44	° ′ 15 56 W	Dec. 2° 52′ N
Long.	1 3 44	4	E.T. 4m 55s
		60)63 44	+M.T.
M.T.P.	15 21 53 0	1 3 44 W	
E.T.	4 55		
A.T.P.	15 21 57 55		
Hour A.	2 2 5		
$\frac{H}{2}$	1 1 2	Cos²	9·98439
p	92° 52′		9·98439
l^1	59 44	Sine	9·99946
2)	152 36	Sine	9·93636
$\frac{p+l^1}{2}$	76 18		2)19·90460
θ	63 38	=Sine	9·95230
$\frac{p+l^1}{2}+\theta$	139 56	Sine	9·80867
$\frac{p+l^1}{2}-\theta$	12 40	Sine	9·34099
Cal. Z. Dist.	44° 8′	=Hav	9·14966

Obs. Alt.	45° 2′	Bearing by
Correction	+ 11	Burdwood N 47° E
True Altitude	45 13	
Corr. for Run	− 3½	
	45 9½	
True Z. Dist.	44 50½	
Cal. Z. Dist.	44 8	
Away	42½′	

Greenwich Date.	d h m s		
Sept.	16 0 0 21		Dec. 2° 53′ N
Long.	1 3 44		E.T. 4m 55s +M.T.
M.T.P.	15 22 56 37		
E.T.	4 55		
A.T.P.	15 23 1 32		
Hour A.	58 28		
$\frac{H}{2}$	29 14	Cos²	9·99646
p	92° 53′		9·99646
l^1	54 44	Sine	9·99945
2)	152 37	Sine	9·93636
$\frac{p+l^1}{2}$	76 18½		2)19·92873
θ	67 6½	=Sine	9·96436
$\frac{p+l^1}{2}+\theta$	143 25	Sine	9·77524
$\frac{p+l^1}{2}-\theta$	9 12	Sine	9·20380
Cal. Z. Dist.	35° 57½′	=Hav	8·97904

Obs. Alt.	52° 58′	Bearing by
Correction	+ 11	Burdwood N 25° E
True Altitude	53 9	
True Z. Dist.	36 51	
Cal. Z. Dist.	35 57½	
Away	53½′	



Scale 6′ to ⅛ inch

Diff. Lat. 58′ S
Dep. 5′ W
Diff. Long. 6′ W

D.R. Latitude	30° 16′ S	Run to noon S 9° E 6′	D.R. Longitude	15° 56′ W
Diff. Latitude	58 S	Diff. Lat. 6′ Diff. Long. 2′ E	Diff. Longitude	6 W
Latitude at obs.	31 14 S		Longitude at obs.	16 2 W
Run to noon	6 S		Run to noon	2 E
Latitude at noon	31° 20′ S		Longitude at noon	16° 0′ W

Simultaneous Altitude of Two Stars.

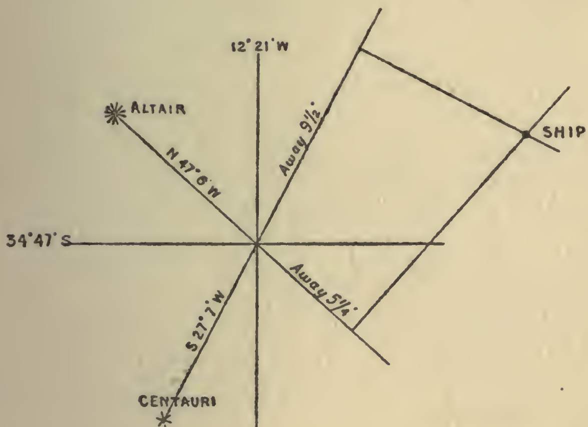
1910. September 18th, at 10.30 p.m. the observed altitude of *Altair* to the N.W. was 33° 27′. The chronometer showed G.M.T. 11h. 21m. 19s.; also the altitude of *a Centauri*, S.W., was 18° 11′, chronometer then 11h. 22m. 47s. Height 20 feet. Position D.R. 34° 47′ S., 12° 21′ W.

	Greenwich Date. d h m s			Long.
Sept.	18 11 21 19			12° 21′ W
	49 24			4
M.T.P.	18 10 31 55			49 24
M.S.R.A.	11 47 58			
R.A.M.	18 22 19 53			
∗R.A.	19 46 25			
Hour A.	2 33 28			
$\frac{H}{2}$	1 16 44	Cos²	9·97519	
p	98° 38′		9·97519	
p'	55 13	Sine	9·99505	
2)	153 51	Sine	9·91451	
		2)	19·85994	
$\frac{p+p'}{2}$	76 55½			
θ	58 20	= Sine	9·92997	
$\frac{p+p'}{2}+\theta$	135 15½	Sine	9·84752	
$\frac{p+p'}{2}-\theta$	18 35½	Sine	9·50355	
Cal. Z. Dist.	56° 33¼′	= Hav	9·35107	

	Greenwich Date. d h m s	M.S.R.A. h. m. s.		∗R.A. and Decl. h. m. s.
Sept.	18 11 22 47	11 46 6	*Altair*	19 46 25
	49 24	1 48		8° 38′ N
		4		
M.T.P.	18 10 33 23		*a Centauri*	14 33 29
M.S.R.A.	11 47 58	11 47 58		60° 28′ S
R.A.M.	18 22 21 21			
∗R.A.	14 33 29			
Hour A.	7 47 52			
$\frac{H}{2}$	3 53 56	Cos²	9·71829	
p	29° 32′		9·71829	
p'	55 13	Sine	9·69278	
2)	84 45	Sine	9·91451	
		2)	19·04387	
$\frac{p+p'}{2}$	42 22½			
θ	19 25½	= Sine	9·52193	
$\frac{p+p'}{2}+\theta$	61 48	Sine	9·94512	
$\frac{p+p'}{2}-\theta$	22 57	Sine	9·59098	
Cal. Z. Dist.	71° 46½′	= Hav	9·53610	

		Bearing by A B C
Obs. Alt.	33° 27′	− ·88
Correction	− 5½	− ·23
True Alt.	33° 21½′	
True Z. Dist.	56 38½	− 1·11
Cal. Z. Dist.	56 33¼	N 47·6° W
Away	5¼′	

		Bearing by A B C
Obs. Alt.	18° 11′	+ ·35
Correction	− 7	+ 1·95
True Alt.	18° 4′	
True Z. Dist.	71 56	+ 2·3
Cal. Z. Dist.	71 46½	S 27·7° W
Away	9½′	



Diff. Lat. 4½ N
Dep. 11½
Diff. Long. 14 E

D. R. Latitude	34° 47 ′ S	(Position of the ship at obs.)	D. R. Longitude	12° 21′ W
Diff. Latitude	4½ N		Diff. Latitude	14 E
Latitude	34° 42½′ S		Longitude	12° 7′ W

Position by Observation of a Planet and the Sun.

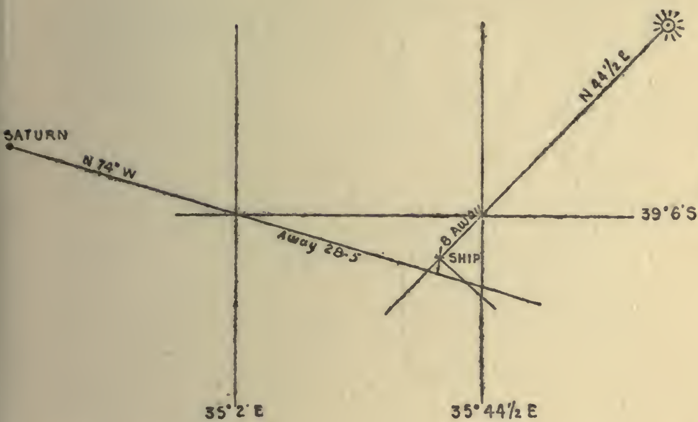
1910. October 3rd, about 5.15 a.m. D.R. 39° 6′ S., longitude 35° 2′ E, the observed altitude of *Saturn* was 20°. Chronometer showed G.M.T. 14h. 43m. 9s., ship ran E. 33′ till about 10 a.m. when the observed altitude of ☉ was 45° 18′. Chronometer G.M.T. 19h. 28m. 31s. Ship then ran E. 12′ to noon. Find the noon position.

Greenwich Date.	h m s	Longitude.		M.S.R.A. h m s
G.M.T.	14 43 9		35° 2′ E	12 41 18
Long.	2 20 8		4	2 18
			60)140 8	7
M.T.P.	17 3 17		2 20 8	
M.S.R.A.	12 43 43			12 43 43
R.A.M.	29 47 0			*R.A. + Dec.
*R.A.	2 14 7			2° 14″ 7′
Hour A.	3 32 53			10° 35′ N
$\frac{H}{2}$	1 46 26	Cos²	9·95138	
			9·95138	
p	100° 35′			
p^1	50 54	Sine	9·99255	
	2)151 29	Sine	9·88989	
			2)19·78520	
$\frac{p+p^1}{2}$	75 44½			
θ	51 17	=Sine	9·89260	
$\frac{p+p^1}{2}+\theta$	127 1½	Sine	9·90221	
$\frac{p+p^1}{2}-\theta$	24 27½	Sine	9·61703	
Cal. Z. Dist.	70 11½	=Hav	9·51924	

D.R. for 2nd pos. 39° 6′ S 35° 44½′ E	h m s		
G.M.T.	19 28 31		35° 44½′
	2 22 58		4
			60)142 58
M.T.P.	21 51 29		2 22 58
E.T	10 41	Dec. 3° 40′ S	
		E.T. 10m 41s +M.T.	
A.T.P.	22 2 10		
Hour A.	1 57 50		
$\frac{H}{2}$	58 55	Cos²	9·98549
p	86° 20′		9·98549
p^1	50 54	Sine	9·99911
	2) 137 14	Sine	9·88989
$\frac{p+p^1}{2}$	68 37		2)19·85998
θ	58 20	=Sine	9·92999
$\frac{p+p^1}{2}+\theta$	126 57	Sine	9·90263
$\frac{p+p^1}{2}-\theta$	10 17	Sine	9·25168
Cal. Z. Dist.	44° 23′	=Hav	9·15431

Obs. Alt.	20° 0′	Burdwood
	−7	S 106° W
		T.B. N 74° W.
True Alt.	19 53	
Corr. for Run	−33	
	19 20	
True Z. Dist.	70 40	
Cal. Z. Dist.	70 11½	
Away	28½′	

Obs. Alt.	45° 18′	Burdwood
	+11	S 135½ E
		T.B. N 44½ E
True Altitude	45 29	
True Z. Dist.	44 31	
Cal. Z. Dist.	44 23	
Away	8′	



Diff. Lat. 5½ S
Dep. 5½ W
D. Lon. 6½ W

Latitude	39° 6′ S		Longitude	35° 44½ E
	5½ S			6½ W
	39° 11½′ S	*Ans.* Lat. 39° 11½′ S. Long. 35° 54′ E.		35 38 E
			To noon	16 E
				35° 54′ E

Position by Observation of Sun and Bearing of Land.

1910. October 13th, at 7.23 a.m. Latitude D.R. 38° 33′ S., longitude 77° 45′ E., the observed altitude of ☉ was 20° 40′. Height 19 feet. Chronometer G.M.T. 12d. 13h. 58m. 46s.; at the same time a point of land (St. Pauls) in latitude 38° 42¾′ S., longitude 77° 34½′ E., bore S. 36° W. true.

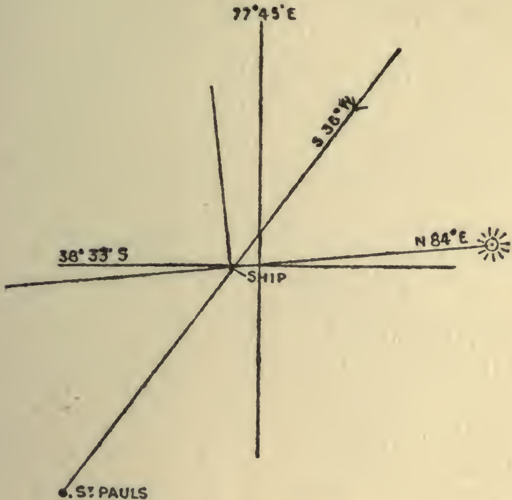
Decl. 7° 23½′ S
E.T. 13m 26s + M.T.

Greenwich Date.	d h m s		Longitude.
October	12 13 58 46		° ′ 77 45 E
Longitude	5 11 0		4
			60)311 0
M.T.P.	12 19 9 46		5 11 0
E.T.	+13 26		
A.T.P.	19 23 12		
Hour Angle	4 36 48		
$\frac{H}{2}$	2 18 24	Cos²	9·91547
			9·91547
p	82° 36½′	Sine	9·99637
l	51 27	Sine	9·89324
	2) 134° 3½′		2)19·72055
$\frac{p+l}{2}$	67 1¾		
θ	46 27½	=Sine	9·86028
$\frac{p+l}{2}+\theta$	113 29¼	Sine	9·96243
$\frac{p+l}{2}-\theta$	20 34¼	Sine	9·54553
Cal. Z. Dist.	69° 9¼′	=Hav.	9·50796

Obs. Alt.	20° 40′	Bearing by Burdwood
Correction	+ 9·5	N 84° E
True Alt.	20 49½	
True Z. Dist.	69 10½	
Cal. Z. Dist.	69 9¼	
Away	1·25	

Lat. D.R.	38° 33′ S
St. Pauls	38 42¾ S
Diff. Lat.	9¾ S

Long. D.R.	77° 45′ E
St. Pauls	77 34½ E
Diff. Long.	10½′ W
Dep.	8¼ W



D.R. Latitude	38° 33'· S	D.R. Long.	77° 45 ' E	Diff. Lat. ¼' S
Diff. Latitude	¼ S		1¾ W	Dep. 1¼' W
				Diff. Long. 1¾' W
Latitude	38° 33¼ S	Longitude	77° 43¼' E	

Double Altitude of the Sun, one very late Sight.

1910. October 9th, at 9.15 a.m. the observed altitude $\odot$ was 39° 10′, G.M.T. 16h. 53m. 49s., D.R. latitude 39° 10′ S., longitude 60° 45′ E., at 11h. 50m. the observed altitude $\odot$ was 57° 18′, G.M.T. 19h. 35s. 9s. Run E. 1° S. 20 miles. Height 20 feet.

Greenwich Date.	h m s		
G.M.T.	16 53 49		
Long.	4 2 40		
M.T.P.	20 56 29		
E.T.	12 24		
A.T.P.	21 8 53		
Hour A.	2 51 7		
$\frac{H}{2}$	1 25 33	Cos²	9·969012
p	84° 5′		9·969012
l	50 50	Sine	9·997680
	2) 134° 55	Sine	9·889477
$\frac{p+l}{2}$	67 27½		2)19·825181
θ	54 51½	=Sine	9·912590
$\frac{p+l}{2}+\theta$	122 19	Sine	9·926911
$\frac{p+l}{2}-\theta$	12 36	Sine	9·338742
Cal. Z. Dist.	50° 51¼′	=Hav	9·265653

Longitude.
60° 40′ E
4
60)242 40
4 2 40

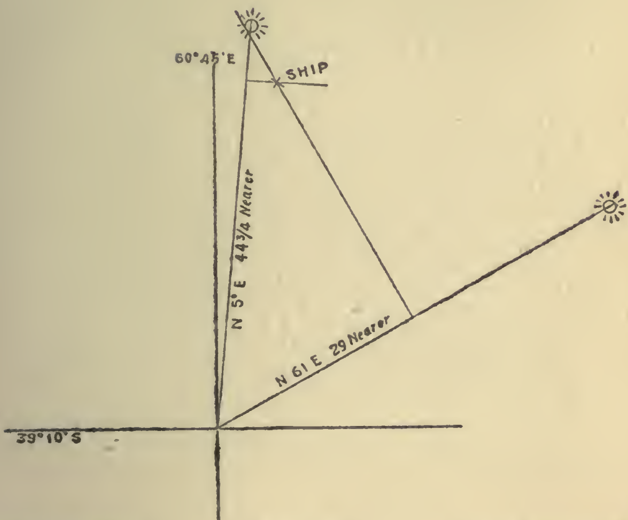
Dec. 5° 55′ S
E.T. 12m 24s
+M.T.

Obs. Alt.	39° 10′	Bearing by
Correction	+ 10½	Burdwood N 61° E
True Alt.	39° 20½′	
Run	+ 17½	
	39° 38′	
True Z. Dist.	50 22	
Cal. Z. Dist.	50 51	
Nearer	29′	

Greenwich Date.	h m s		
G.M.T.	19 35 9		
Long.	4 2 40		
M.T.P.	23 37 49		
E.T.	12 26		
A.T.P.	23 50 15		
Hour A.	9 45		
$\frac{H}{2}$	4 52	Cos²	9·999902
p	84° 2′		9·999902
l	50 50	Sine	9·997641
	2) 134 52	Sine	9·889477
$\frac{p+l}{2}$	67 26		2)19·886922
θ	61 23½	=Sine	9·943461
$\frac{p+l}{2}+\theta$	128 49½	Sine	9·891573
$\frac{p+l}{2}-\theta$	6 2½	Sine	9·022229
Cal. Z. Dist.	33° 16¾′	=Hav	8·913802

Decl. 5° 58′ S
E.T. 12m 26s
+M.T.

Obs. Alt.	57° 18′	Bearing by
Correction	+11	Burdwood N 5° E
True Alt.	57° 29′	
True Z. Dist.	32 31	
Cal. Z. Dist.	33 16¾	
Nearer	44¾′	



D.R. Latitude	39° 10′ S	$\frac{1}{24}''$ to a mile.	D.R. Longitude	60° 45′ E
Diff. Latitude	44 N	Diff. Latitude 44° N.	Diff. Longitude	10 E
		Dep. 8° E. Diff. Long. 10′		
Latitude in	38° 26′ S		Longitude in	68° 55′ E

The run to noon puts her another mile E. which agreed, both latitude and longitude, with the noon position by meridian altitude and chronometer methods.

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